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SITUATION AWARENESS BASED AUTOMATIC BASESTATION DETECTION AND COVERAGE RECONFIGURATION IN 3G SYSTEMS

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Abstract - A novel technique for inserting basestations on an ad-hoc basis is investigated in this paper. Sector retraction and extension is used to reshape the network coverage area. Basestations are generally added to the network whenever there is a need to meet an increasing capacity demand. The replanning exercise can be both costly and time consuming. Situation Awareness (SA) is the enabling functionality that allows a network redesign without a drain on resources. The simulation involves loading the network to capacity and evaluating the performance of adding a basestation 'on the fly'. Spectrum efficiency is the measure of performance used. Reconfiguration of the network area is performed by controlling the power level of the downlink pilot channel through the use of a genetic algorithm (GA). The performance of the algorithm is determined by its ability to reconfigure and redistribute the traffic. The technique is shown to offer a flexible and simple solution to the problem of UMTS network replanning for additional capacity.

Keywords – Situation awareness, adaptive coverage, genetic algorithm, network planning.

I. INTRODUCTION

The deployment of a third generation network involves many new challenges. As there is no frequency planning involved in CDMA cellular systems, the key issue in network planning is to determine the location and density of the required basestations. Finding optimal basestation placements exacerbates the complexity of network planning. Future networks will require the deployment of thousands of basestations in microcellular and picocellular environments. In view of the physical constraints and inaccuracies of fixed planning methods (such as inaccurate propagation models), an automatic planning method is desirable. Self-Organisation is one technique that can organise future wireless networks and make them more adaptive [1]. The ability to deploy self-organised networks depends on the extent that basestations can be made 'Situation Aware' [2]. This involves making basestations more aware of their surroundings (e.g. location of neighbouring basestations or building structures), so that they can react to imbalances such as changes in the propagation environment or the traffic level within the network.

In a previous paper [3], adaptive macrocellular coverage based on 'Situation Awareness (SA)' was examined in the

context of basestation failure. It was established that basestations could extend their coverage to serve users from partially or fully deactivated cells provided that certain parameters were exchanged within the network. This paper aims to study how cells can detect the presence of new basestations and adapt their coverage accordingly. An adaptive coverage system with such functionality will reduce the requirement for extensive network replanning. Using situation awareness, basestations can be deployed throughout the network with minimum co-ordination. An adaptive coverage algorithm will then be used to reconfigure the coverage of each basestation. This algorithm will continue to adapt coverage in the event of changes in the propagation environment, such as the introduction of new high rise buildings.

A. Addition of new basestations in the network area

New basestations are added to the network area so as to increase the capacity and thereby help to provide a better Grade of Service (GoS). The possibility of introducing basestations without the need for extensive replanning is appealing but the main focus is to provide increased capacity from a limited frequency resource. The proposed paper examines how automatic basestation detection and coverage reconfiguration could be implemented. The following strategy is similar to the process of cell splitting commonly used in GSM. Adjacent sectors are extended and retracted to reshape the coverage area. A specific example of introducing a mobile basestation near a hotspot, such as a stadium or a shopping mall, is studied in this contribution. However, if required the concept can be extended to more general cases.

B. Issues to consider with dynamic placement of basestations

1) Positioning error

Basestation positioning is vital to achieve good interference protection and to cover the desired geographic area. In order to meet the high capacity demands of next generation wireless systems, operators will have to deploy networks with small cell radii. Macrocellular networks can be made relatively insensitive to erroneous basestation positioning through the application of power control on the downlink [4]. Accurate planning, from a propagation point of view, is not essential if an appropriate power control algorithm is

employed. However, these statements are only applicable for macrocells, where relatively simple propagation models such as COST 231 are applicable. Generally, field strength prediction variations are more pronounced in a microcellular environment [5]. Given this situation, there was a strong need to repeat the analysis performed in this paper using a deterministic microcellular propagation model [6].

2) Soft handover area

One powerful variable that directly affects network capacity is cell size. In general, the larger the cell size, the lower the capacity. Having the ability to reduce the cell radius increases capacity, but only if soft handover and softer handover are optimised. Non optimisation leads to capacity being wasted by single mobiles communicating unnecessarily with several base stations simultaneously. The inherent disadvantage of excessive handover can be overcome through the use of hierarchical cell structures with adaptive radio resource management [7].

II. SIMULATOR AND SCENARIO DESCRIPTION

A simulator has been devised for the purpose of modelling a hexagonal UMTS network. Basestations can be placed and activated/deactivated on the hexagonal grid of the simulator. Mobile users can be deployed uniformly or hotspots can be introduced over the simulation area. It is also possible to estimate individual path loss values and relative distances. Different sector configurations can also be selected and the coverage map of the service area can then be evaluated.

The basestations were arranged on a regular grid and the COST 231 symmetrical propagation model applied to both links.

A. Basestation activation scenario

The initial scenario assumes a network comprising of 9 equally sized cells. A new basestation is introduced next to a hot spot cell. The neighbouring sectors detect this change and react by reorienting and decreasing their coverage in order to accommodate the new cell. Assuming a circular array of antennas and beamforming capabilities at the basestation, soft sectors can be directed in the wanted direction [8]. Network coverage reshaping is achieved by rotating and extending sectors.

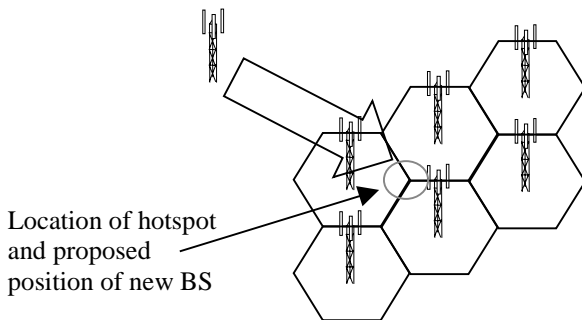


Figure 1: Addition of basestation in simulation area

In our analysis, three sectors (*candidate sectors*) from three different cells are used for the insertion of a new cell. The range of the candidate sectors is controlled by adjusting the pilot power; this is a function of range as demonstrated in Figure 2. In order to minimise intercell interference sectors are rotated to reduce sector overlap.

B. Simulation parameters

A Monte Carlo approach is used to simulate the network and the above-mentioned scenario. A snapshot technique is used for each user deployment since mobility is not emulated. A single simulation snapshot consists of the simulation of the power control algorithm of all users in the network. Once the algorithm of all users converges the outage probability of a single snapshot is calculated as the percentage of users whose mean received SIR is less than their required target. The blocking probability is set to be the percentage of users blocked as a consequence of the loading factor attaining a limit of 0.75.

The simulation parameters are given in Table 1 [9]. The network is simulated with 10 cells (9 initial + 1 new). Only data from two cells are analysed, i.e. the hotspot and the new cell. The surrounding cells are included to produce a more accurate interference condition.

C. Assumptions

The following assumptions are made in the modelling and simulation process.

- Perfect power control (finite range)
- Voice activity factor not taken into account
- No limitations on available codes for downlink

Table 1: Simulation Parameters

Parameter	Description
Simulation	Static with downlink only (FDD mode)
Network size	10 basestations
Sectors	Six sectored
Carrier frequency [MHz]	2000
Cell radius[m]	800
Bit rate [kbps]	15
Downlink SIR target [dB]	6.7
Processing Gain	256
BS max output power [W]	20
Pilot threshold sensitivity [dB]	-14
Soft HO window	3dB

D. Performance Measure

Spectrum efficiency is used as a performance measure. In general, non-uniform traffic degrades the overall performance of the system. The quality becomes poor due to

the increased interference in dense traffic zones. In less dense areas, the link quality largely exceeds the threshold. The dispersion of the communication quality as such restricts the system capacity [10]. The addition of the new basestation alleviates these problems, but the use of SA illustrates the fact that no planning is required since intercell interference is managed efficiently through the use of an adaptive algorithm. Furthermore, the flexibility of automatic detection and coverage reconfiguration prevents a drain of human and financial resources for the network operator, while optimising spectrum efficiency.

III. BASESTATION DETECTION

Neighbouring basetations can be informed by the RNC (Radio Network Controller) of any new insertion of cells in the network. Alternatively, each basestation can keep a record of its neighbouring first tier of cells. At regular time intervals, each basestation monitors the beacon signal of its neighbouring cells and updates the neighbour list. In the eventuality that a new basestation is introduced, sector retraction is performed in order to accommodate the basestation.

A. Beacon power adjustment

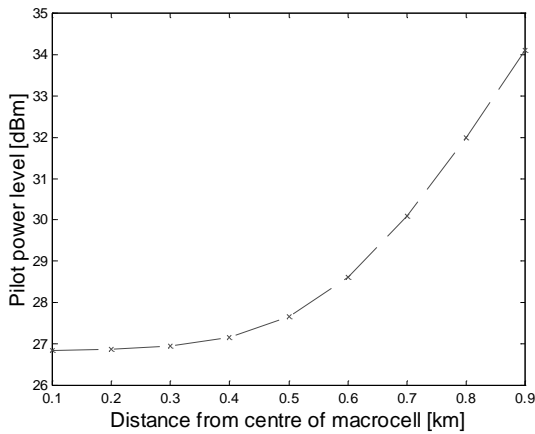


Figure 2: Pilot power given as a function of range

The pilot channel is a downlink channel that is used by the basestation to send control signals to mobile stations for new call admissions and soft handover control. This beacon channel defines the cell radius and as such the proposed algorithm is based on the control of beacon power settings to reshape the network area. A similar approach has been used in the context of dynamic load sharing [11], whereby users from heavily loaded cells are forced into handover mode by a process of cell shrinking. The same argument is applied in this case but variations in the beacon power setting are used to reconfigure the network whenever a new basestation is detected. The pilot channel power is calculated from the equation of the received pilot chip energy given below [12]:

$$\left(\frac{E_c}{I_0} \right)_{lk} = \frac{G_{lk} P_k^L / R_c}{(G_{lk} P_k^T + \sum_{j=1; j \neq k}^N G_{lj} T_j + \eta) / W} \quad (1)$$

Where G_{lk} denotes the link gain on the path between a mobile at location l and a basestation k . W represents the total spread bandwidth and R_c the chip rate. P_k^T and P_k^L are the amount of power devoted to the traffic and pilot channels respectively. T_j is the total power available in the j -th cell. Figure 2 shows the pilot strength required for different mobile-basestation separation distances from the sector origin. Using this curve it is estimated that a pilot strength of 31.6dBm will define a cell radius of 800m.

B. Situation Awareness based Coverage Reconfiguration

W-CDMA systems are inherently dynamic, the process of cell breathing is a good example how cells can adjust their load. On the other hand, GSM type systems are less flexible and badly placed basestations will always affect the general network performance due to an absence of any averaging mechanism. Coverage reconfiguration can be viewed as a means of exploiting load diversity within the system. By introducing a new basestation the algorithm equalises the load in a group of cells controlled as a cluster.

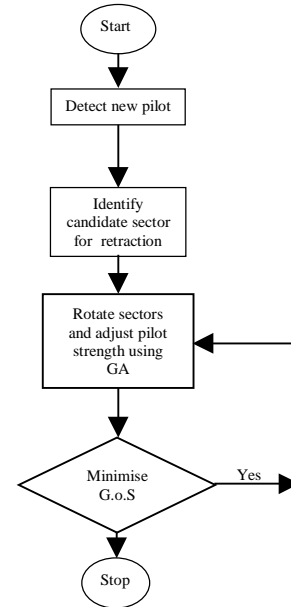


Figure 3: Coverage reconfiguration algorithm

There are no constraints for positioning a new basestation on the 'fly'. From an analysis viewpoint, we will restrict these locations to the apex of three neighbouring basestations as illustrated in Figure 1. If hexagonal tessellation is assumed and a coverage reconfiguration scenario as described above is used, then three sectors from three different cells are engaged in retraction in order to reshape the network area.

Participating cells must then decide which sectors to engage in retraction. Figure 3 outlines the principle.

C. Genetic Algorithms (GA)

The GA is derived from evolution and genetics [13]. The term *chromosome* refers to a candidate solution to a problem encoded as a bit string. The *population* represents the search space of potential solutions. There are three main operators in GA: *Selection*, *Crossover* and *Mutation*. Selection selects chromosomes in the population for reproduction. The fitter the chromosome, the more times it is likely to reproduce. *Crossover* refers to the fact that ‘high quality’ parent chromosomes recombine to produce high quality offspring candidate solutions. Traits from the most dominant individuals will therefore survive into the next generation. Finally, *Mutation* is the operator that randomly flips bits in a chromosome.

The canonical GA consists of an initial population of n randomly generated l -bit chromosomes. The fitness of each chromosome is evaluated using a fitness function $f(x)$. Subsequently, a pair of parent chromosomes is selected from the current population, the probability of selection being an increasing function of fitness. With probability p_c the pair of chromosomes is recombined to form two offspring. Finally, mutation of the two offspring occurs at each locus with probability p_m and the current population is replaced with the new population.

D. Problem definition

The problem objective is to reshape the W-CDMA coverage while minimising outage probability and blocking probability. The solution consists of finding the optimum values of the pilot powers at the three sectors and of the newly inserted basestation.

3.3.1 Chromosome encoding and fitness function

The pilot power values are represented as a power vector and converted to binary for bit string representation. An 8-bit representation is chosen to encode each transmitter level in the vector string. The initial population is composed of 100 individuals and is generated so that the pilot power of each sector has a random power level ranging from 0 to 36dBm (the latter value being the maximum pilot power used in macrocells).

The fitness function used in the GA is given below:

$$f(x) = \frac{1}{(\text{Blocking probability} + 1) + (\text{Outage probability} + 1)} \quad (2)$$

The denominator contains parameters to be minimised. Each chromosome solution is evaluated using equation 1. Figure 4 illustrates the fitness landscape for 100 deployed users and 100 generations. The parameter values are listed in Table 1.

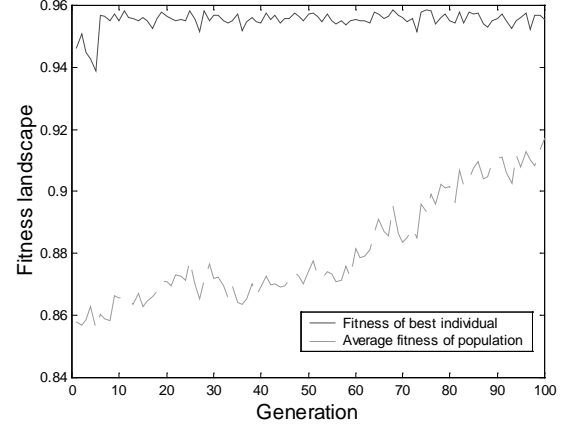


Figure 4: Fitness landscape for a deployment of 55 users (15 Kbps voice service)

Table 2: Parameter values

Parameter	Value
Recombination probability	0.7
Mutation probability	0.001
Population size	100
Number of runs	100

E. Traffic hotspot

A traffic hotspot was introduced at the fringe of the first sector of the reference cell. This relates to a scenario when there is a peak demand in a concentrated area during busy hour. In this case, 80% of users were distributed uniformly and the remaining 20% were distributed according to a two dimensional Gaussian distribution with a standard deviation of 100m.

F. Benchmarking effectiveness of SA

Hypothetically in a three-sector reconfiguration scenario, if perfect sectors, hexagonal geometry and cell radii of r are assumed then the maximal cell area leading to minimal overlap is $\frac{3\sqrt{3}r^2}{2}$. As a result the newly inserted cell will

have a maximum radius of $\frac{\sqrt{3}r}{3}$. Sectors are also rotated by

30 degrees in the process to (as far as possible) maintain a tight hexagonal tessellation. A second new basestation with dimensions as calculated above is inserted at the exact location next to the hotspot. However, SA is not utilised (i.e. sector retraction is not performed and pilot levels are not optimally varied). This benchmark aims to demonstrate that Situation Awareness can deliver superior performance, with the addition of extra capacity, due to its ability to manage intercell interference and to adapt to local conditions.

IV. NUMERICAL RESULTS

The Grade of Service is defined as [14]:

$$GoS = \chi + P_{bl} \quad (3)$$

where χ represents the outage probability and P_{bl} the blocking probability. Figure 5 illustrates that the use of SA results in a gain of 65 % in capacity if sector retraction is used to manage intercell interference.

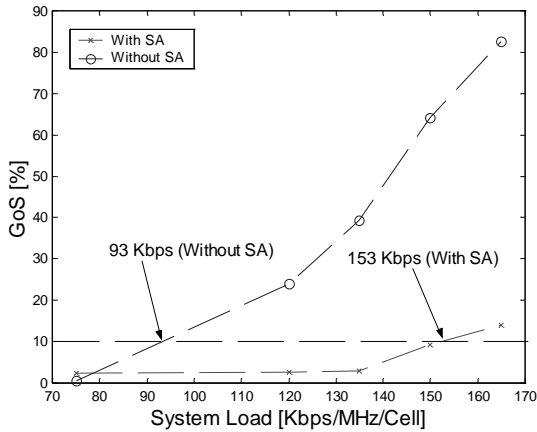


Figure 5: Spectrum efficiency for a specified GoS (10%)

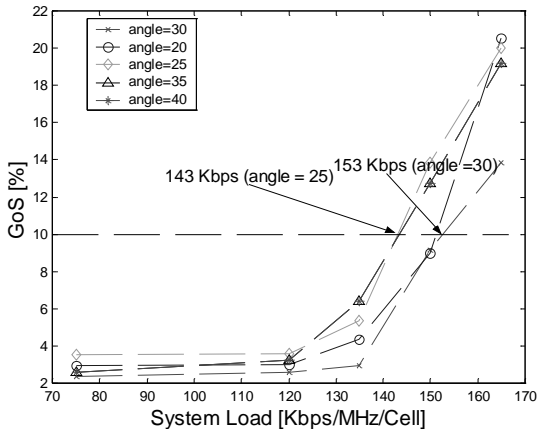


Figure 5: Spectrum efficiency for different sector orientation

Sector orientation was varied from 20 to 40 degrees and the Monte Carlo simulations repeated in view of establishing the performance of the algorithm. The algorithm performs well and is relatively insensitive to orientation with a maximum variation of 7% in capacity.

V. SUMMARY AND CONCLUSIONS

In this paper a novel technique to reconfigure the coverage when a new cell is added to the network has been demonstrated. Sectors from adjacent cells can be retracted to accommodate the newly inserted basestation. This is made

possible by controlling the pilot power of the respective sectors. In view of making this implementation feasible, neighbouring basestations should be in a position to monitor any new insertion. This information could be communicated by the RNC or alternatively be detected by the basestations themselves. The ability to be able to monitor their environment and take corrective action forms part of the Situation Awareness functionality. The algorithm was tested in a scenario where a new cell is inserted next to a hotspot. A benchmark was used to establish the net gain. It was observed that the use of SA provided capacity gains up to 65% for a specified GoS target of 10%. The algorithm proved to be robust to sector orientation, as such for a variation of 20 to 40 degrees, the maximal gain reduction was a mere 7%.

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